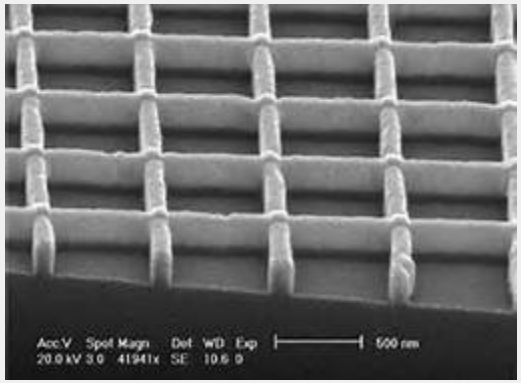
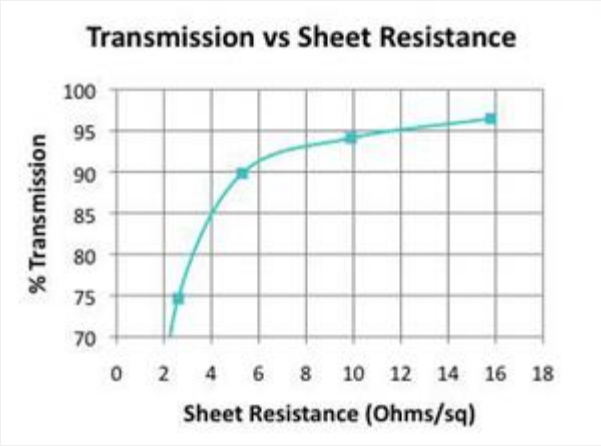


# Metal Grids for OLED Transparent Conductors

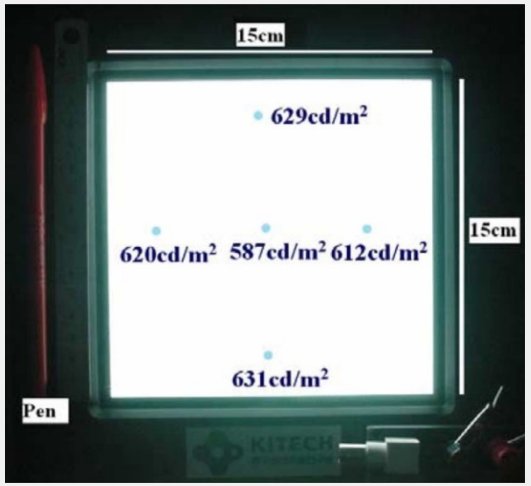
## DOE SSL Workshop, January 29, 2014




Mike Carmody
Chief Scientist
Intrinsiq Materials

# Why Grids? Performance Drivers

- The best transparent conductors really aren't conductive enough (sheet resistance > 5 Ω/sq)
- There are voltage and luminance drops as the current flows laterally
- Heat can build up locally

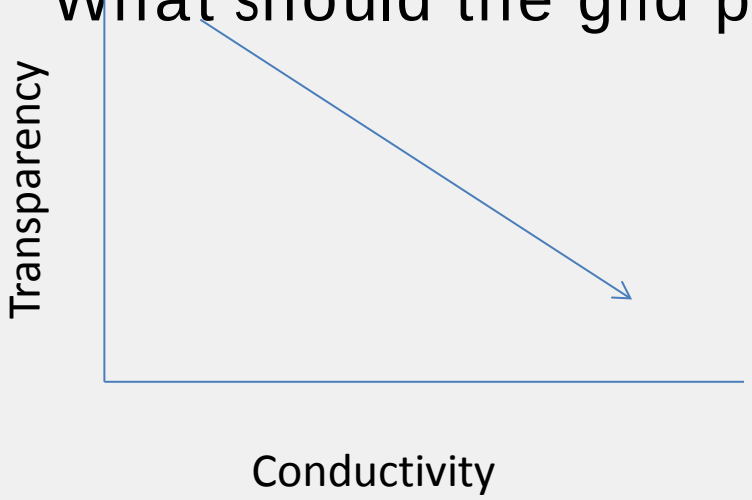


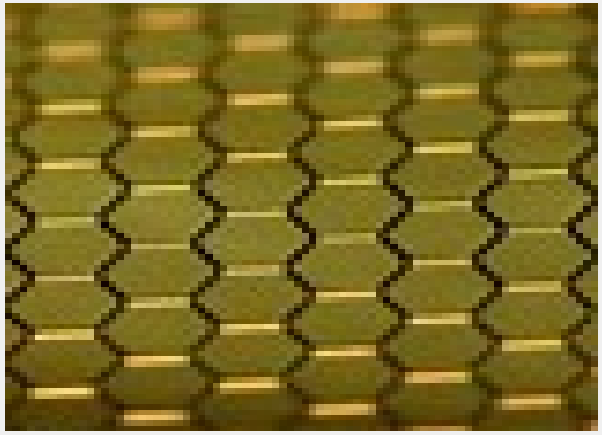

- As dimensions of the panels increase in size to greater than a few centimeters grids are thought to become necessary

Image from: J Park, J Lee, D Shin, S Park; J Disp Tech, 5(8) 2009

# Grids bring their own set of problems

- T = 1-w/h Increased Grid Width= Decreased Transparency
- We can increase the height of the metal, but that affects the next coated layer
- What metal should be used?
- What should the grid pattern be?



# Printing Conductive Grids

- Expected to be significantly less expensive than sputtering and photolithography*
- Allows rapid change of pattern design (this might be especially useful for prototyping)
- Can printed grids meet the performance requirements
  - Low Sheet resistance < 1 Ω/sq -- Thicknesses < 1 µm
  - Optical T > 90% --Line width < 150 µm

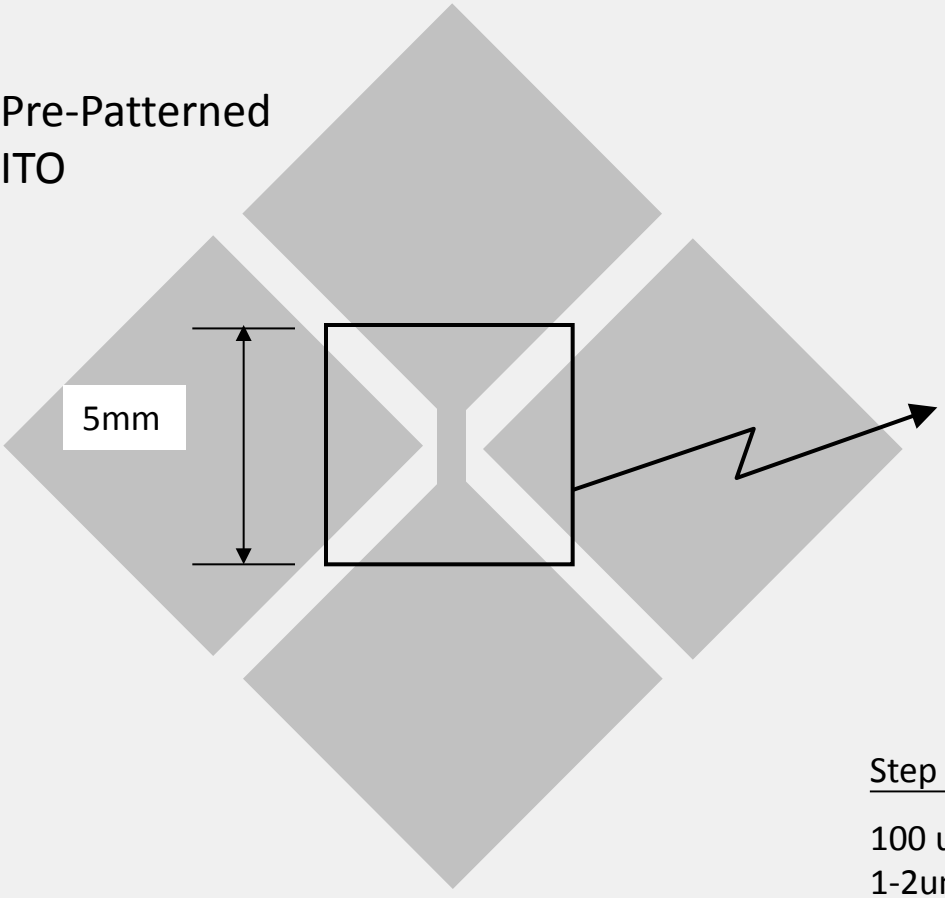
*H. Zhang, DOE SSL Workshop, Jan 30, 2013

# Printing Considerations

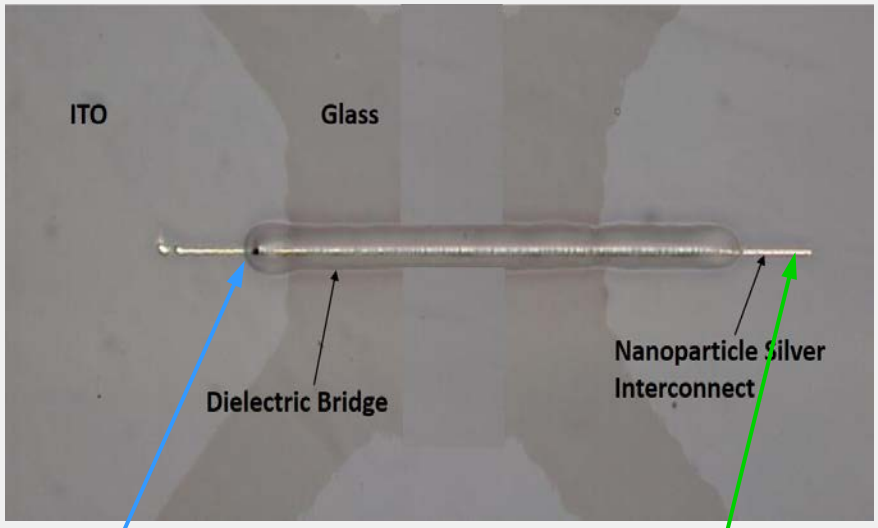
- Nano Ag has been the metal of choice for printing inks
- Resistivity is still not good enough (5-10X bulk Ag)
- Does it have to be Ag? Au is expensive and there are worries about Cu and Al oxidation
- Inkjet printing may not be able to provide fine enough lines to meet fill factor requirements
- Experimentalists have used laser sintering or other deposition techniques to provide lines </= 10 µm

# Touch Screen Printing Market Opportunity: Bridge/Jumper Circuit

Pre-Patterned
ITO




After Aerosol Jet Printing




Step #1: Insulator

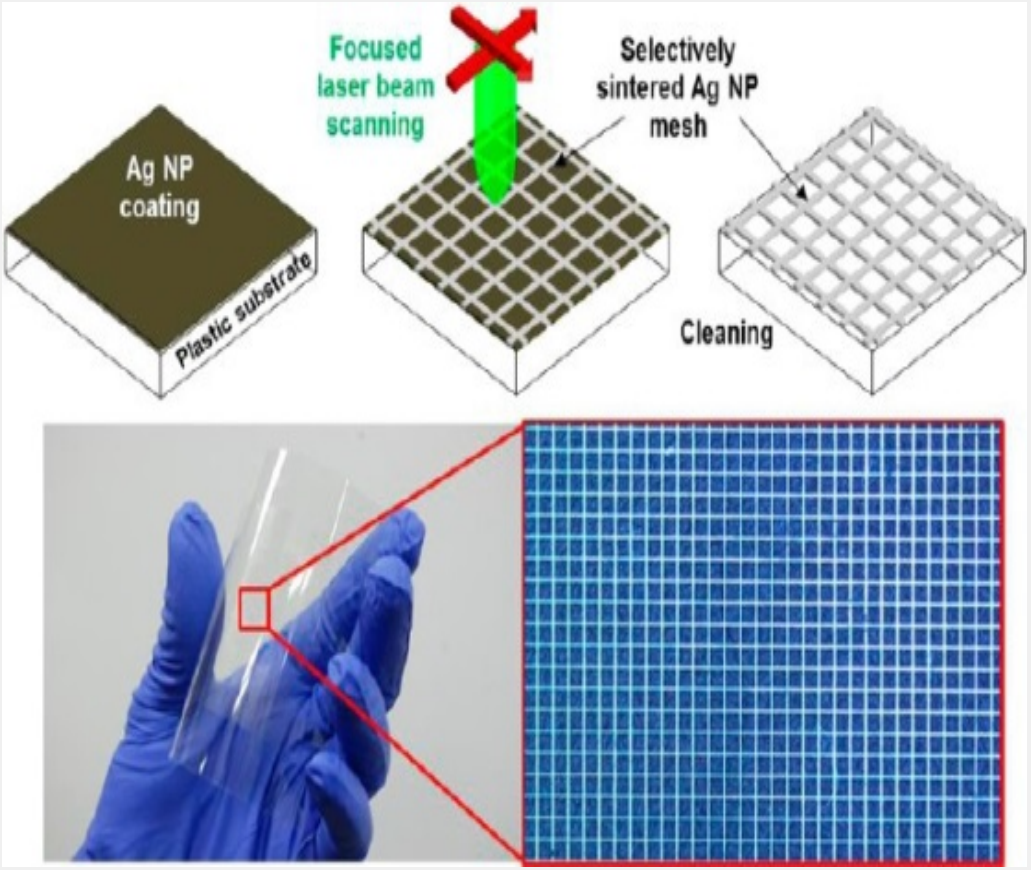
100 um wide X 180um long X
1-2um thick

Step #2: Conductor

10um wide X 230um long X
0.3-1um thick

From Optomec, used by permission

# Ag Lines by Selective Laser Sintering[1]




-PEN substrate

-10 µm lines

-~150 nm thick

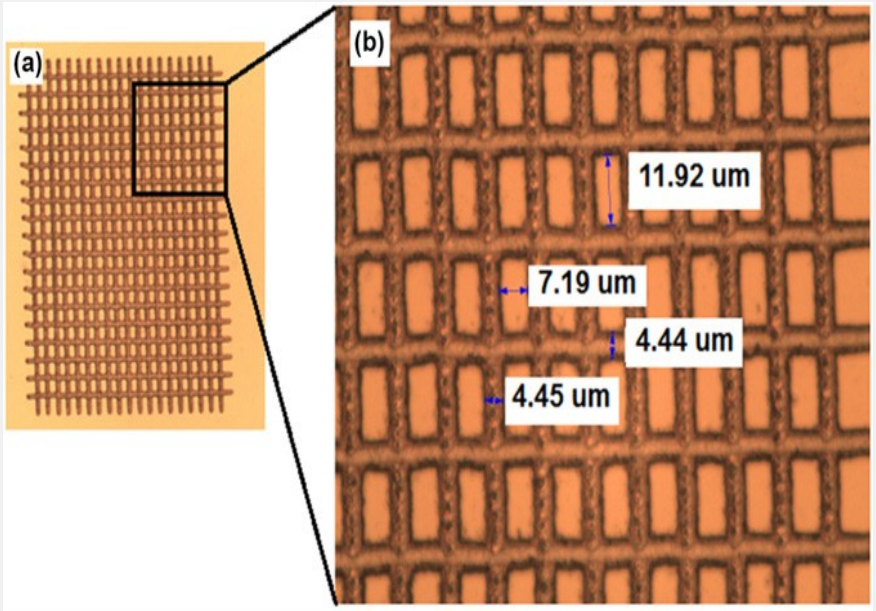
-4.3 X bulk copper

-9 to 22 Ω/sq

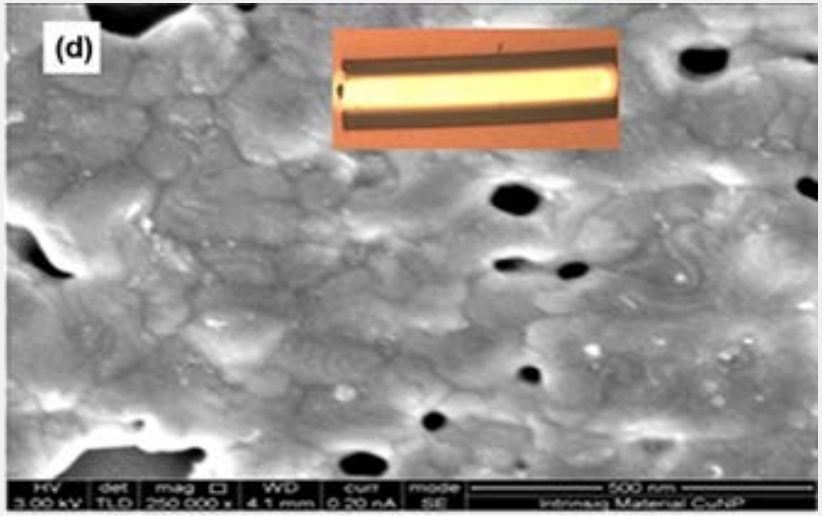
-80-92 % T

S.H. Ko, ACS Nano, 2013 7(6) 5024-5031

# Laser Sintering of Cu Nanoparticles[2]




-Ambient conditions, no oxidation
-Spin coated on Glass
-Pattern height is 450 nm
- ~ 4.5 µm wide lines
- ρ = ~2 - 3X bulk Cu

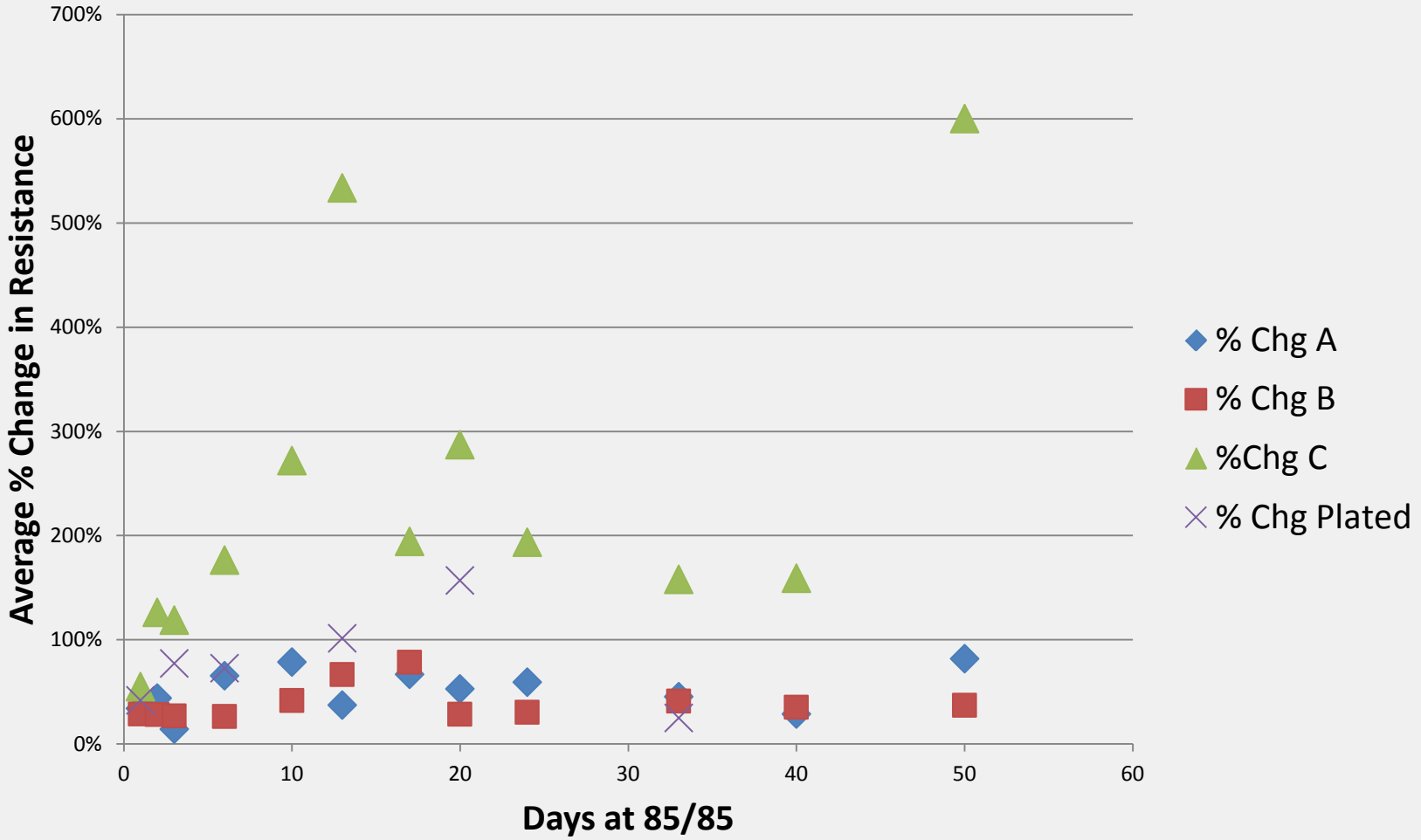



M. Zenou, O. Ermak, A. Saar, and Z. Kotler, J. Phys. D: App. Phys. **47** (2014) 025501
Used by permission

# Can Printed Cu Withstand Oxidation?

- Spin coated and laser sintered three different Cu inks
- Compared to a similar Cu trace prepared by printing a seed layer and electroless plating Cu on top of it
- Kept in a chamber at 85°C and 85% RH
- Measured changes in resistivity over time

# Cu Can Withstand Oxidation!



# Conclusions

- Printed metal grids offer the possibility of improved cost and improved performance
- Lines of widths necessary for high transmittance have been produced by a variety of techniques
- These lines need to be combined with OLED panels to determine interactions
- *michaelcarmody@intrinsiqmaterials.com*